Shot Mechanics

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Main Injector/Recycler Department

Run Coordinator 1 Aug – 1 Dec

Shot Mechanics

- Introduction
- Operational Planning
- Description of a Shot
- How are we doing ?

Introduction to Collider Shots

- The Function
  - to prepare the accelerator complex for (re)loading protons and pbars into the Tevatron Collider for producing luminosity
- The Goal
  - to efficiently load the maximum intensity of protons and pbars,
  - bring the protons and pbars into collision at both interaction regions with minimal loss and maximum possible luminosity,
  - and minimize dead time between Collider fills.

Operational Planning, strategies

- To provide:
  - maximum (initial & integrated) luminosity
  - and maintain the ability for improvement in initial luminosity, lifetime, and reliability the following strategies have been adopted:
    - Alternate weeks of "stack 'n store" and dedicated Collider Studies (3 to 5 shifts)
    - Take advantage of "no stack – no store" periods for accelerator improvement studies
    - Focused studies (aimed toward a specific problem) between store termination and Collider filling
    - Extended periods of "stack 'n store"
    - M&D periods as needed

Operational Planning, the team

- The Run II Coordination Team – develops the operational strategy
  - Run II Project Leader
    - Overall responsibility for the Run II project
  - Run II Coordinator
    - Determines daily/weekly store and studies schedule
    - Shot strategy / parameters on a store by store basis
    - Primary interface between Beams Division and Experiment Run coordinators
  - Deputy Run II Coordinator
    - Assist Run II Coordinator in daily operations
  - Shot Data Analysis Coordinator
    - Coordinate the efforts of SDA team and Machine Departments
  - Machine Coordinators
    - Coordinating studies and shutdown requests for their individual machine (MI, Pbar,Tev,etc.)
- Accelerator Operations (in conjunction with Accelerator Physicists and support personnel)
  - Execute the plans
  - Provide feedback for shot analysis and improvement

Operational Planning, communication

To accomplish the coordination of the Collider program a series of strategy, planning, and briefing meetings are carried out.

- Monthly Run II Strategy Meeting
- Run II Steering Committee (M)
- Run II Scheduling Meeting (M,W,F)
- Monday Morning Meeting w/ Division Head
- Monday Studies Planning
- All Experimenters Meeting (M PM)
- Run II Shot Analysis (Th)
- Department Studies Planning meetings

See pages 7-9 for more information

Operational Planning, communication 1

- To accomplish the coordination of the Collider program a series of strategy, planning, and briefing meetings are carried out.
  - Monthly Run II Strategy Meeting (Directorate, CDF, D0, Operations, Beams Div. Head, Run II Project leader, Run coordinator, special guests)
    - Review performance of previous month
    - Determine the running strategy for next month
  - Run II Steering Committee made up the Division management, Run coordination team, and Department Heads
    - Status of outstanding action items
    - Issues inhibiting performance/strategies
    - Plans for the upcoming week
    - Issues requiring discussion, coordination and/or decision

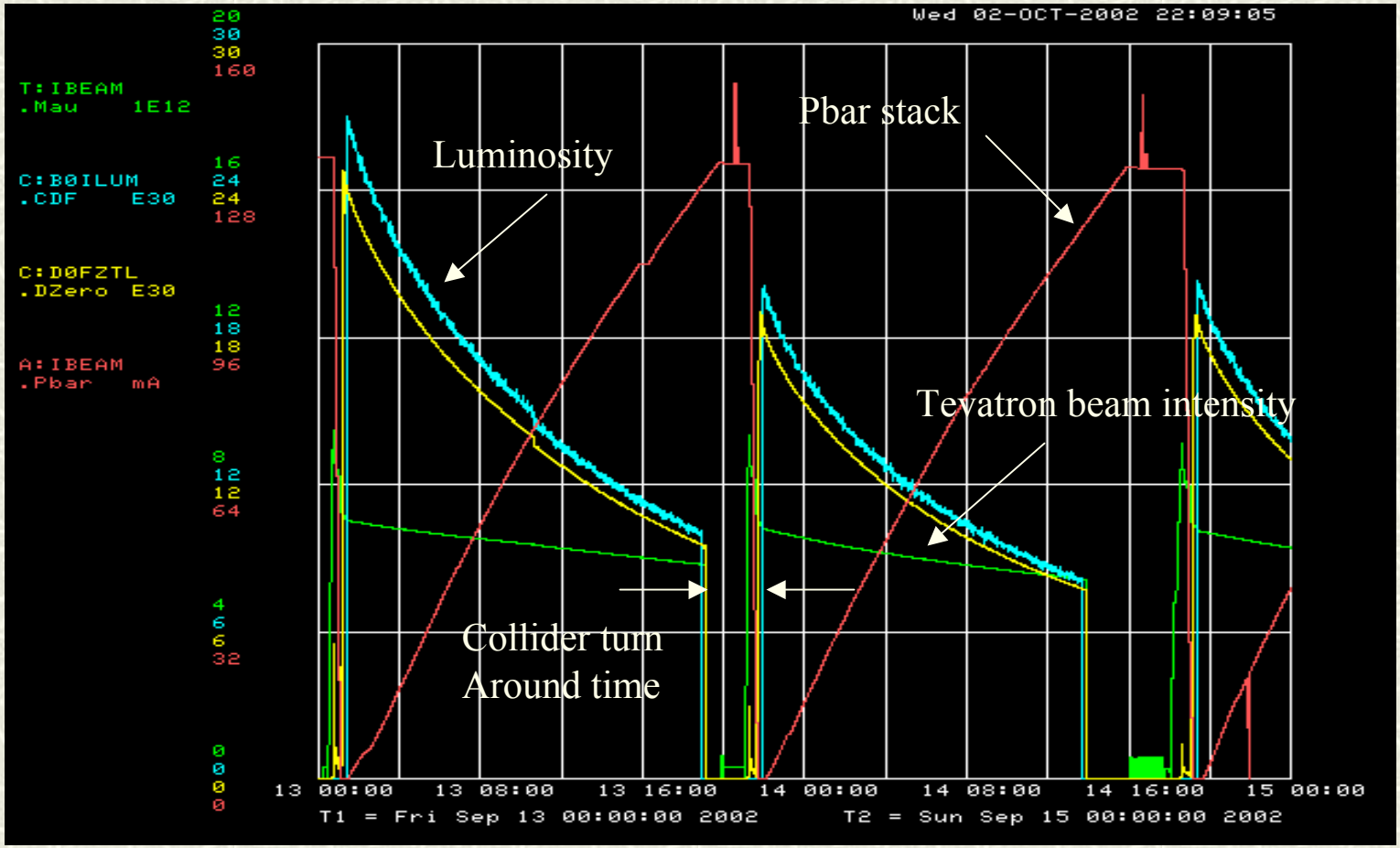
Operational Planning , communication 2

- Run II Scheduling meeting (9:00 AM M,W,F) with the all Beams Division Departments, the Directorate, local DOE, and Experiment Coordinators
  - the operational status of the accelerator and the experiments is discussed
  - and the operational plan for the day/week is announced.
- Monday morning meeting with the Beams Division Head, Run IIA Project Leader, the Run Coordinator (and Deputy)
  - discuss the previous weekend
  - and the plans for the week prior to Run II Scheduling meeting
- Monday Studies Planning meeting with the Run II Coordination team and machine coordinators (open to all)
  - Study plans and requests of each department for the week are discussed
  - A detailed plan (by shifts) is worked out to coordinate the activities of all accelerators

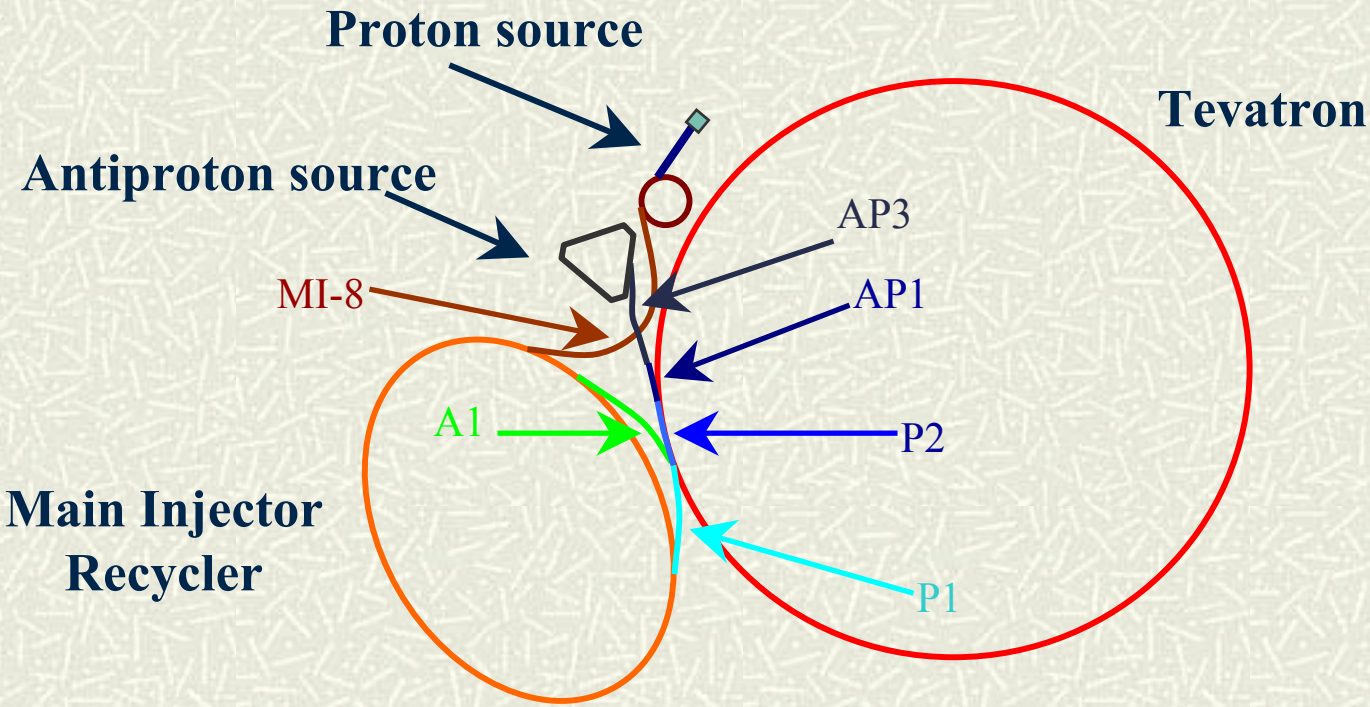
Operational Planning , communication 3

- All Experimenters Meeting
  - Status Reports from Accelerator Operations, Run Coordinator, and all Experiments
  - Presentation of the Accelerator schedule for the week
- Run II Shot Analysis (Run II Coordination Team, Shot Analysis Team, Machine Coordinators)
  - Discussion of the prior weeks shots
  - Shot analysis issues
  - Presentation of Accelerator Study results
- Department Studies meetings
  - Detailed discussion of individual accelerator issues and studies
  - Develop detailed study plans and priorities

Stack ‘n Store - an example



Shot Set-Up – the Lay of the Land



Resources

- Manpower
  - Operations… the "front line"
  - Machine Specialist
  - Machine Department Physicists
  - Support Department Personnel
- Accelerator Modes / state devices / clock events
  - Accelerator states are used by "front ends" such as low level RF, flying wires (and other instrumentation) and S*hot* D*ata* A*nalysis* protocol to determine what to do, when, and how.
  - State variables are used to communicate between sequencers
  - Annunciation of Machine/Transfer states
- Software Sequencers

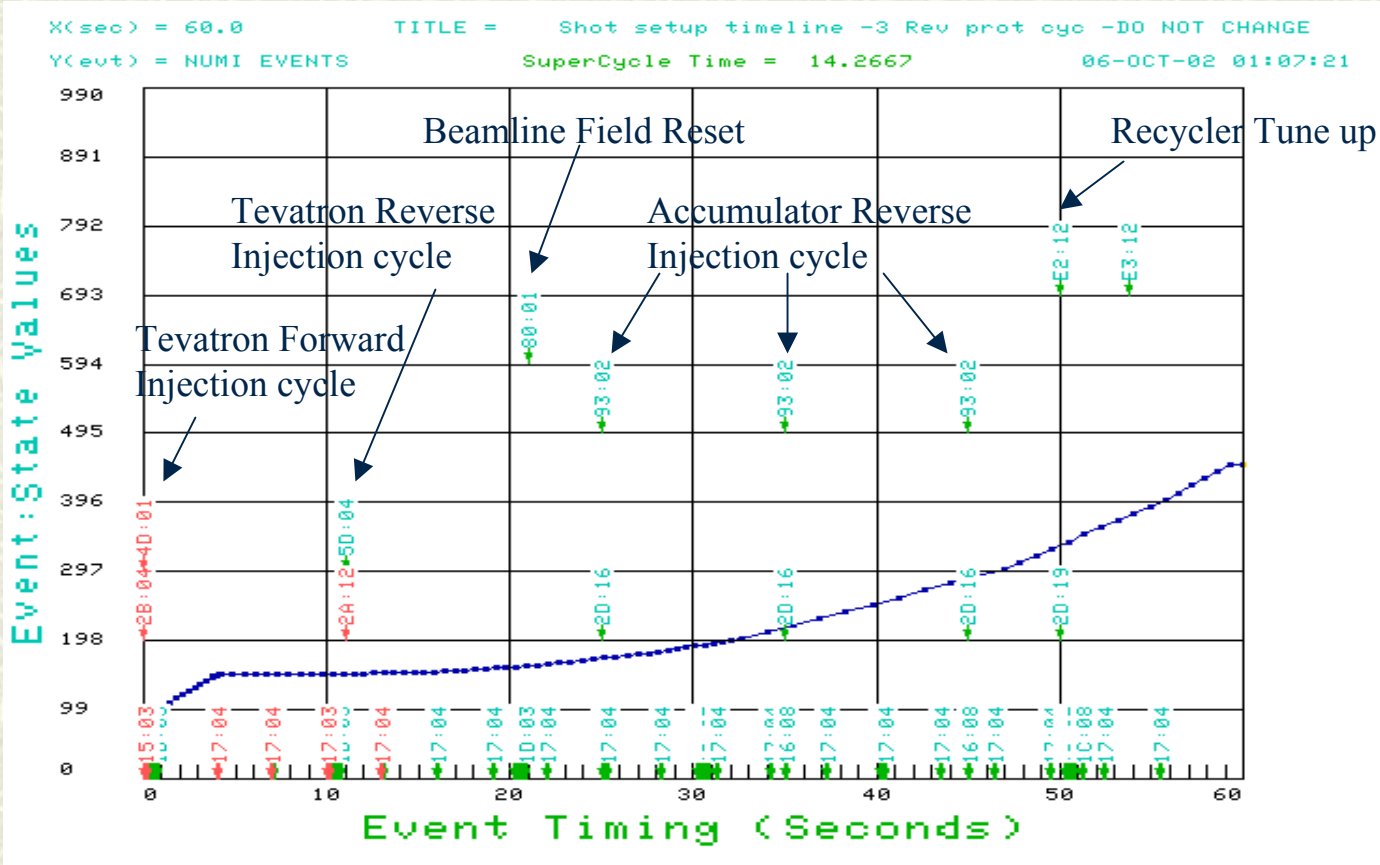
Clock Events and States

- Clock events (see pages 14-15)
  - Operation of the accelerators (and most hardware) are clock event driven
  - Used by hardware to trigger a waveform or process
- Beam sync events
  - Beam-synchronous clock system used in synchronous transfers, triggering kicker systems, RF systems, diagnostics, instrumentation
- Accelerator States (see pages 16-19)
  - Used by "smart" front end computers to signal a "state" change and some action by the devices connected to this front-end.
  - Ex: Machine High-level Mode, Collider state, Accumulator Lattice State, Pbar transfer state, Main Injector transfer state, Tevatron collimator state, Tevatron next bunch…

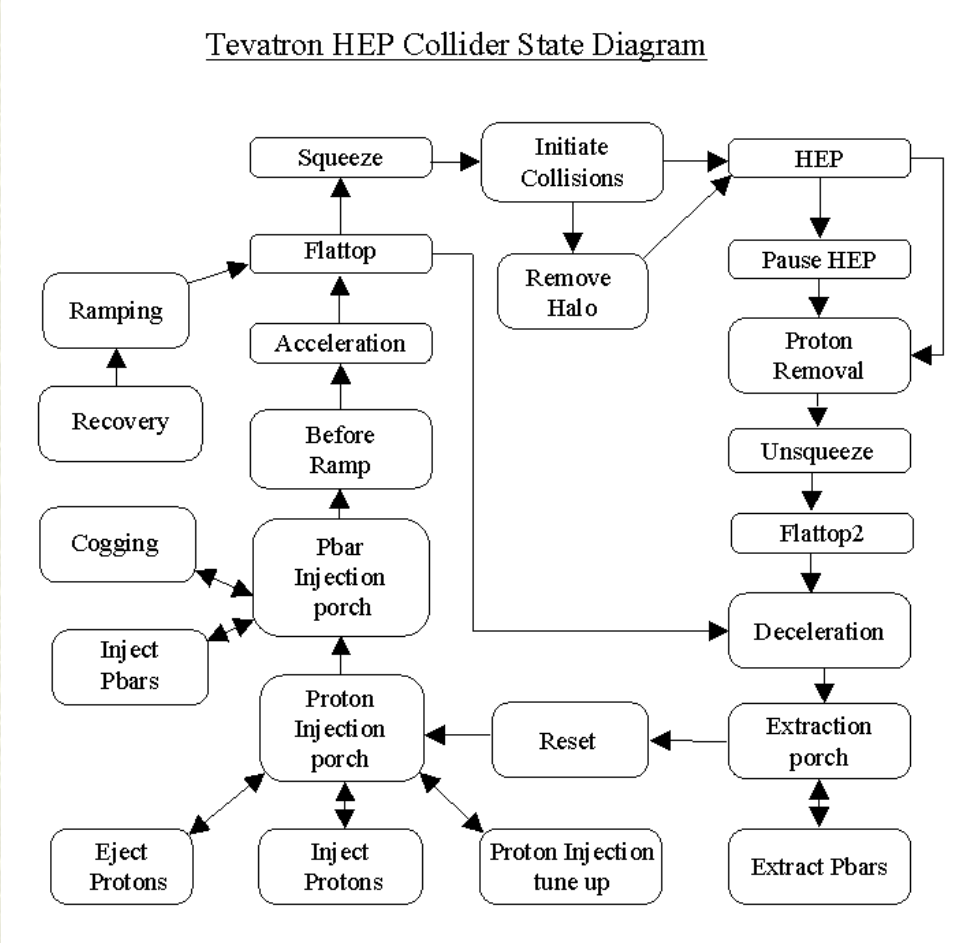
Time Lines

- Accelerator cycles are clock event driven from a master “Time Line Generator”
- Standard Time Lines
  - Stacking
  - Forward/Reverse injection tune up
  - Loading final protons
  - Unstacking and loading pbars

TLG module for Forward/Reverse Injection Tune up



Tevatron HEP Collider State Diagram



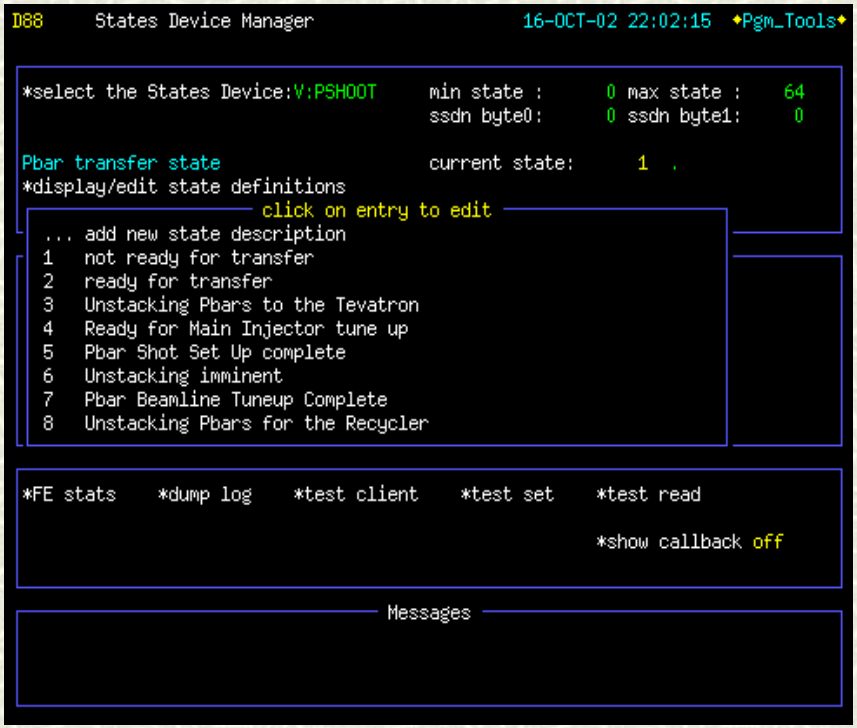
Tevatron States

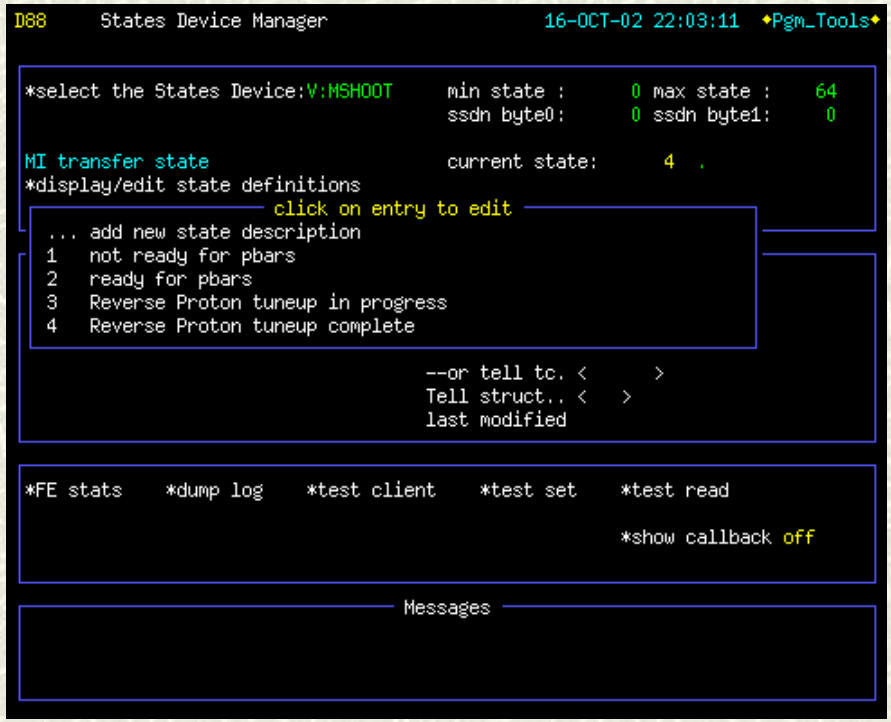
1	Proton Injection Porch	Event $43 (Start of Tevatron fron porch.)
2	Proton Injection tune up	Event $2B+$4D; $5C is echo of MIBS 7C
3	Eject Protons	Event $2A+$5D; $55 is echo of MIBS D8 (Reverse injection.)
4	Inject Protons	Event $2B+$4D; $5C is echo of MIBS 7C
5	Pbar Injection Porch	Event $C3 (Opens injection helix.)
6	Inject Pbars	Event $2A + $40; $5B is echo of MIBS 7B
7	Cogging	
8	Before Ramp	Event $C4 (Increments LBMDAT and removes injection orbit bump.) Event $C2 (Marks Before Ramp state.)
9	Acceleration	Event $42; preceded by $63 (Start of the Tevatron ramp.)
10	Flattop	Event $45; followed by $62 (Start of Tevatron flattop.)
11	Squeeze	Event $C5 (Starts the Low Beta Squeeze) Event $C4 (Increments LBMDAT and advances squeeze one step. Used during a parse or luminosity leveling.)
12	Initiate Collisions	Event $C6 (Increases chromaticity and removes separator 2-bumps.)
13	Remove Halo	- (Leave option open for new event)
-	Smooth during store	Event $61 (Smooth orbit during accelerate/squeeze) Event $67 (Smooth orbit during decelarate/unsqueeze)
14	HEP	Event $CB (Marks beginning of HEP) Event $CE (Marks end of HEP)

Tevatron States, con't.

- 15 Pause HEP - (This state used for studies/tune up with stored beam.)
- 16 Proton Removal Event $69 (Start proton removal. Starts ramp for chromaticity, separator 2-bumps, and dogleg magnets.)
  Event $6C - (After proton removal. Starts ramp turning off dogleg and ramping separators to zero.)
- 17 Unsqueeze Event $C9 (Starts Low Beta Unsqueeze.)
  Event $C7 (Decrements LBMDAT and decreases squeeze one step. Used during a parse or luminosity leveling.)
- 18 Flattop2 - (Leave option open for new event)
- 19 Deceleration Event $6D; preceded by $63 (Start of Tevatron down ramp.)
- - Deceleration (without squeeze) Event $6E; preceded by $63 (Start of Tevatron down ramp when no low beta squeeze was done.) (Not implemented yet.)
- 20 Extraction Porch Event $44; followed by $62 (Start of Tevatron back porch.)
- 21 Extract Pbars (Events $20+$54; $5F is echo of MIBS D6)
  These events depend on pbar recycling and may change!
- 22 Reset Event $41 (Tevatron ramp reset.)
- 23 Recovery
- 24 Ramping

Transfer States for Pbar and Main Injector

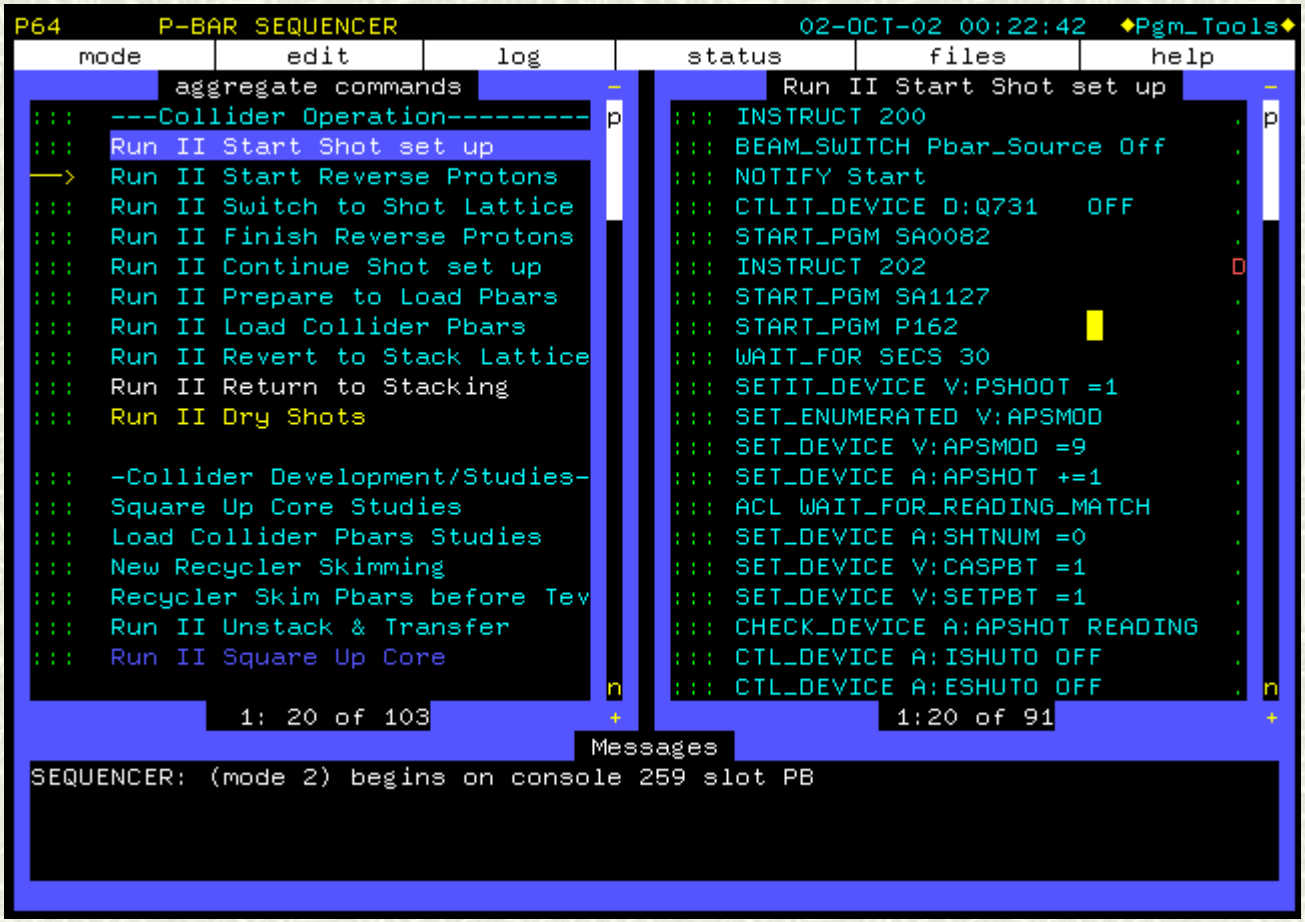




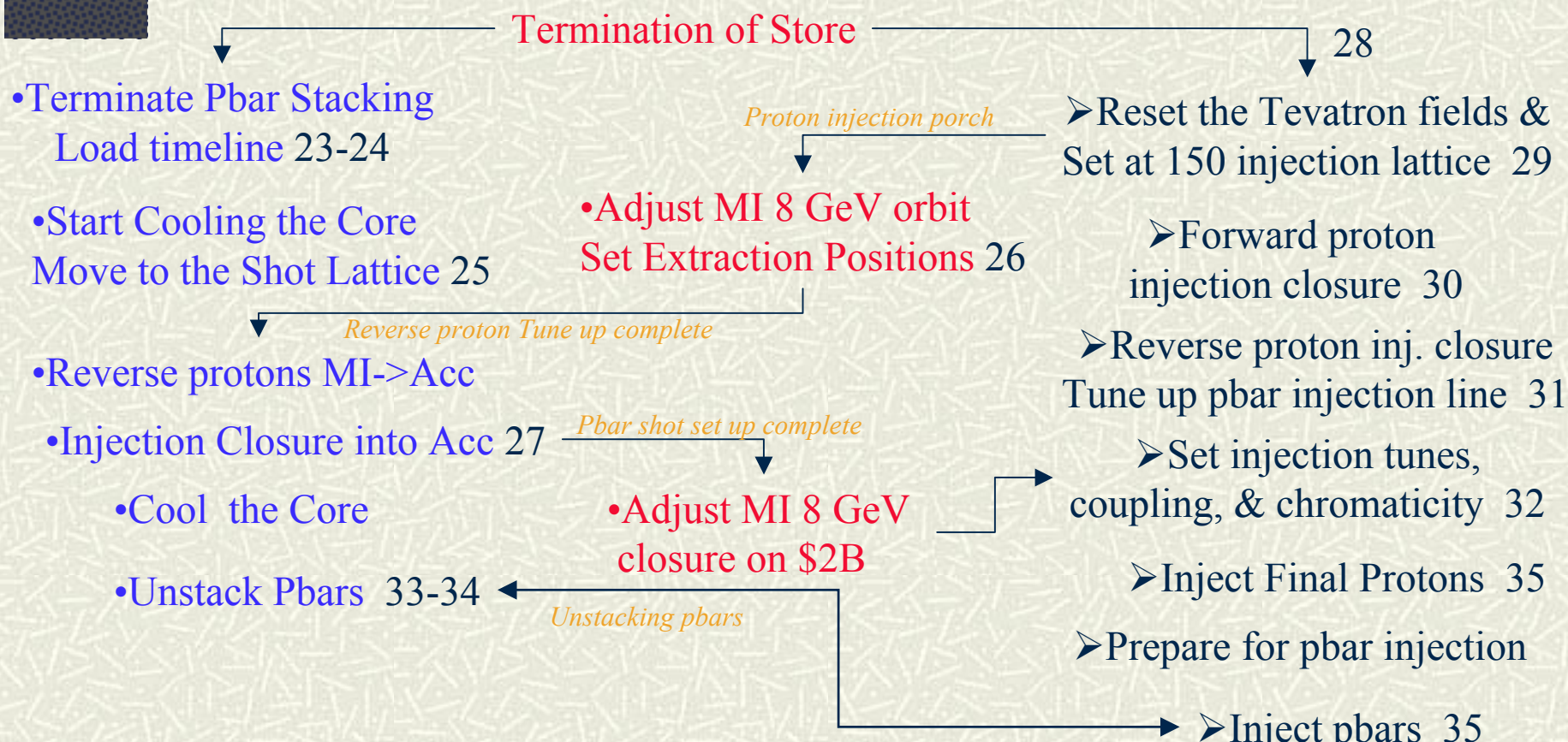
Sequencers, the master controller

- The preparation of the accelerators to “supply”, “prepare” and “accept” and “deliver to collisions” are controlled by Operations using “Sequencer” application programs.
  - Provide a structured way to perform the same task in identical fashion
  - Provide instruction and feedback to the Operator
  - Integrate “special purpose” application programs.. such as closure programs.
  - Some commands and special purpose applications require operator intervention and human feedback based upon guidelines.
  - Communication between accelerators via special “state variables”

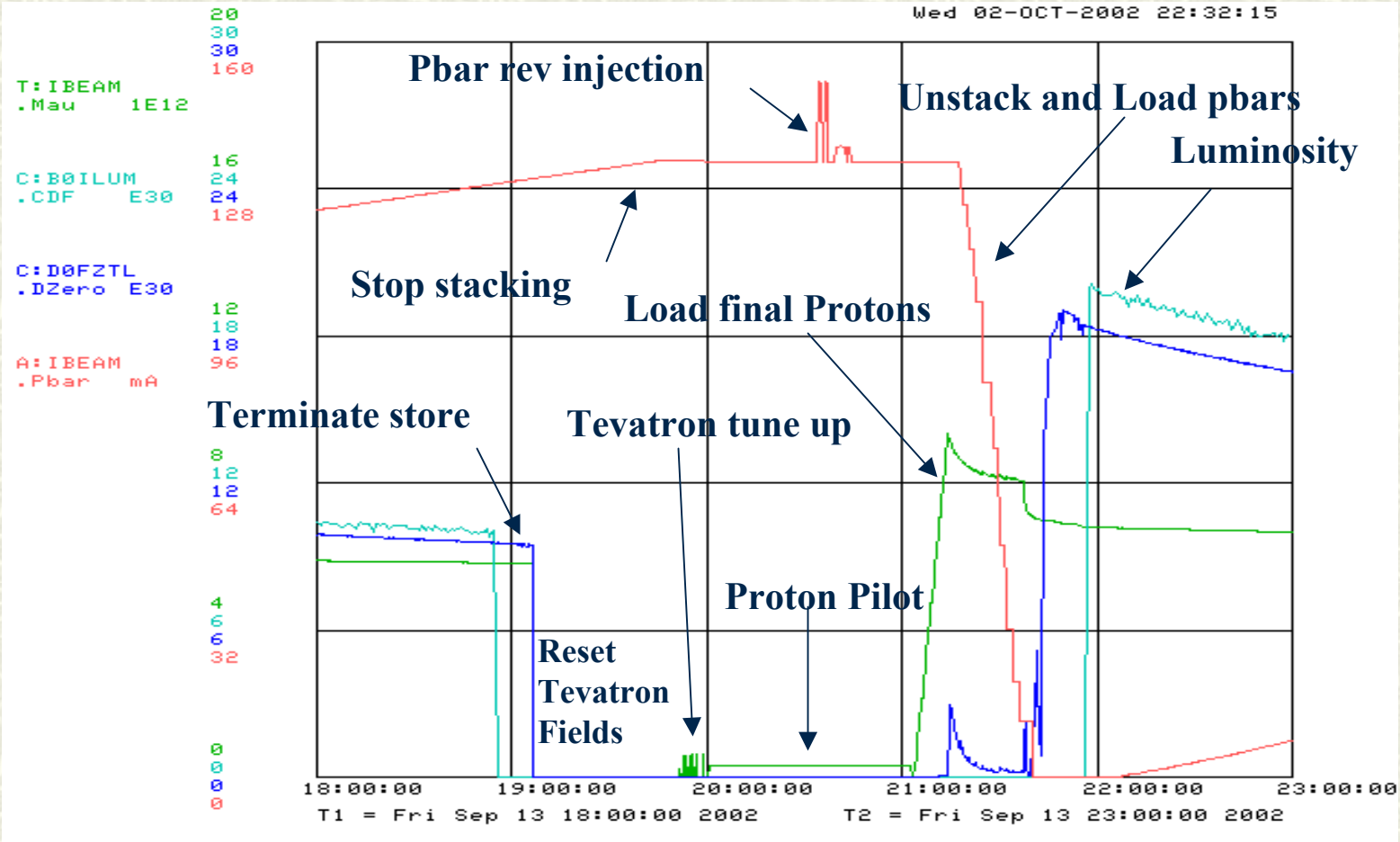
Pbar Sequencer



Mechanics of Shot set up



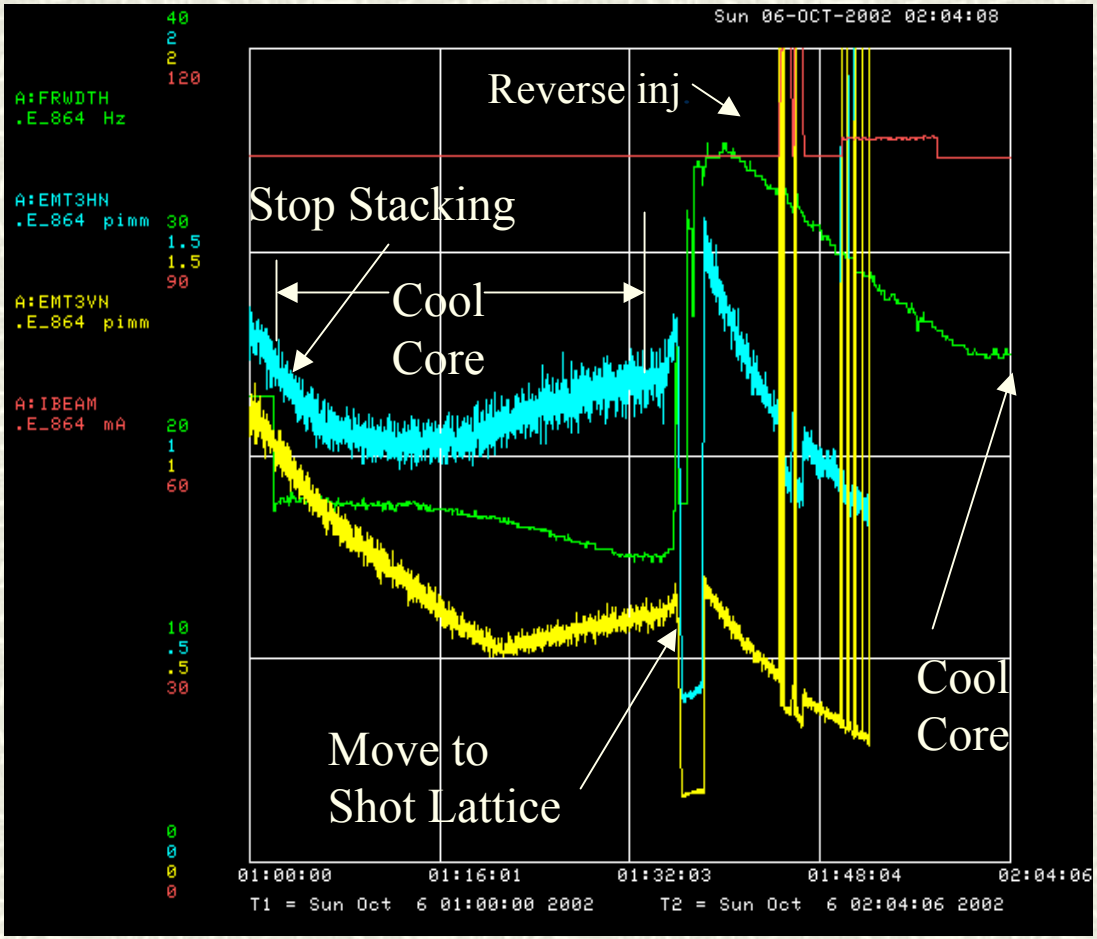
Anatomy of a Shot



Cool Core and Move to Shot Lattice

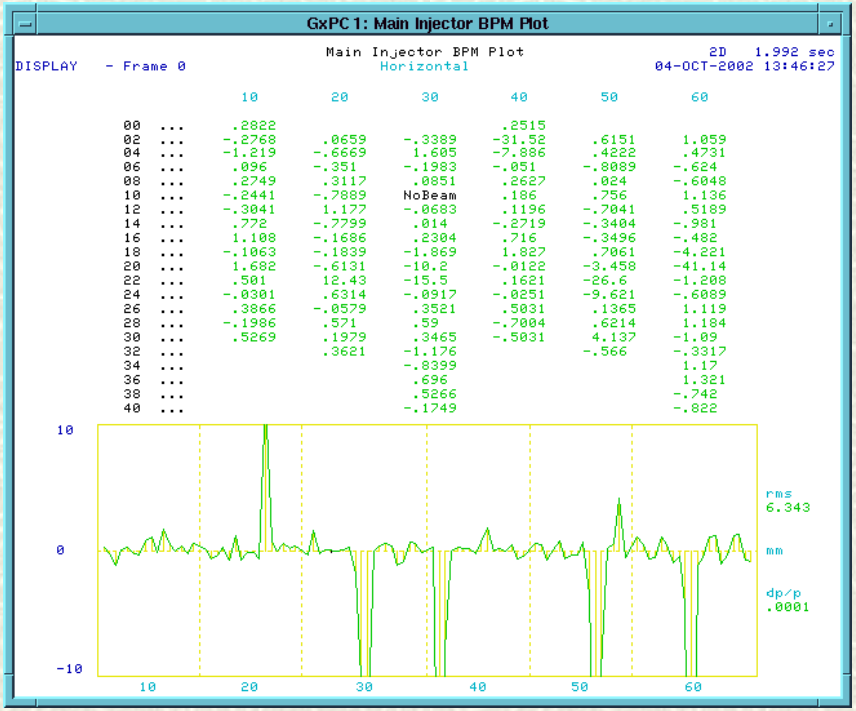
Stacking Lattice
Upgraded for Run II
2-4 Gz cooling upgrade (reduced eta)

Shot Lattice
Similar to Run I lattice
Lower transverse emittance
Increased eta to reduce intra-beam scattering

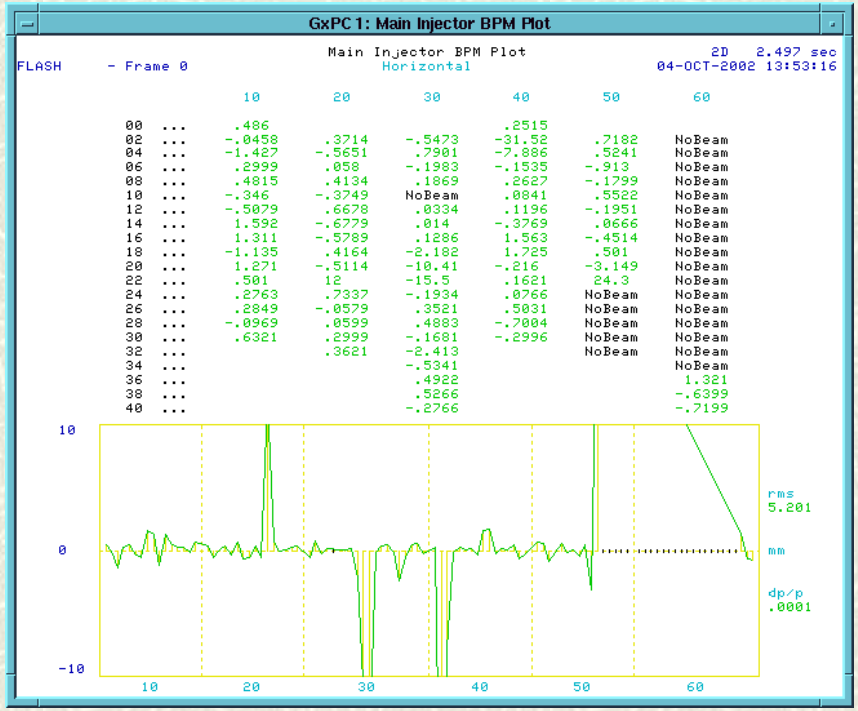


Check/Adjust MI Orbit Positions

> Once the Tevatron is at 150 GeV and while the Core is being cooled and moved to Shot Lattice



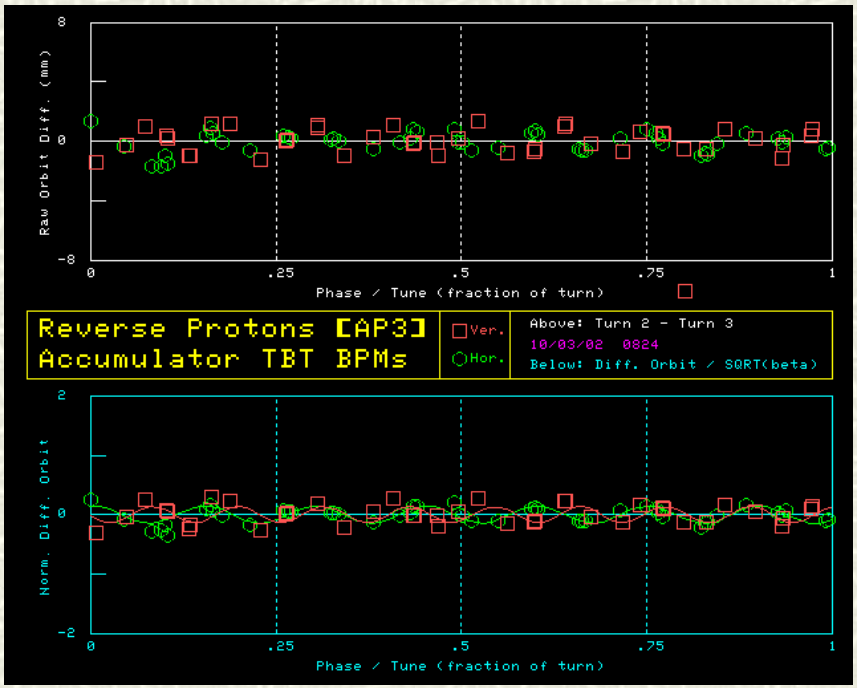
The MI closed orbit is checked / adjusted

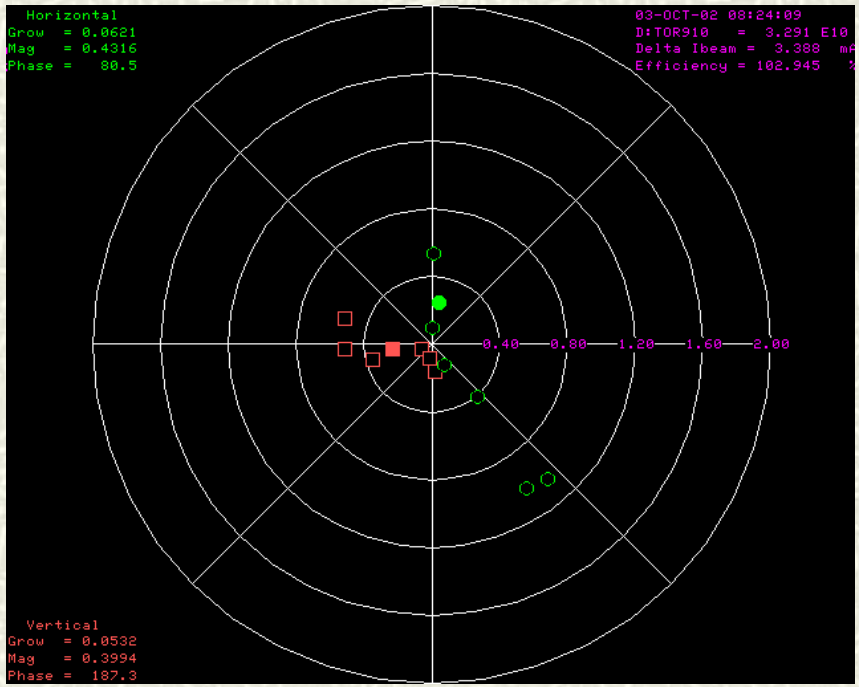


The MI extraction positions are checked / adjusted

Injection Closure into the Accumulator

> Final tune up procedure before cooling the core and unstacking pbars.





Adjust Horizontal and Vertical trims in AP3 to minimize injection oscillations on to the Accumulator extraction orbit

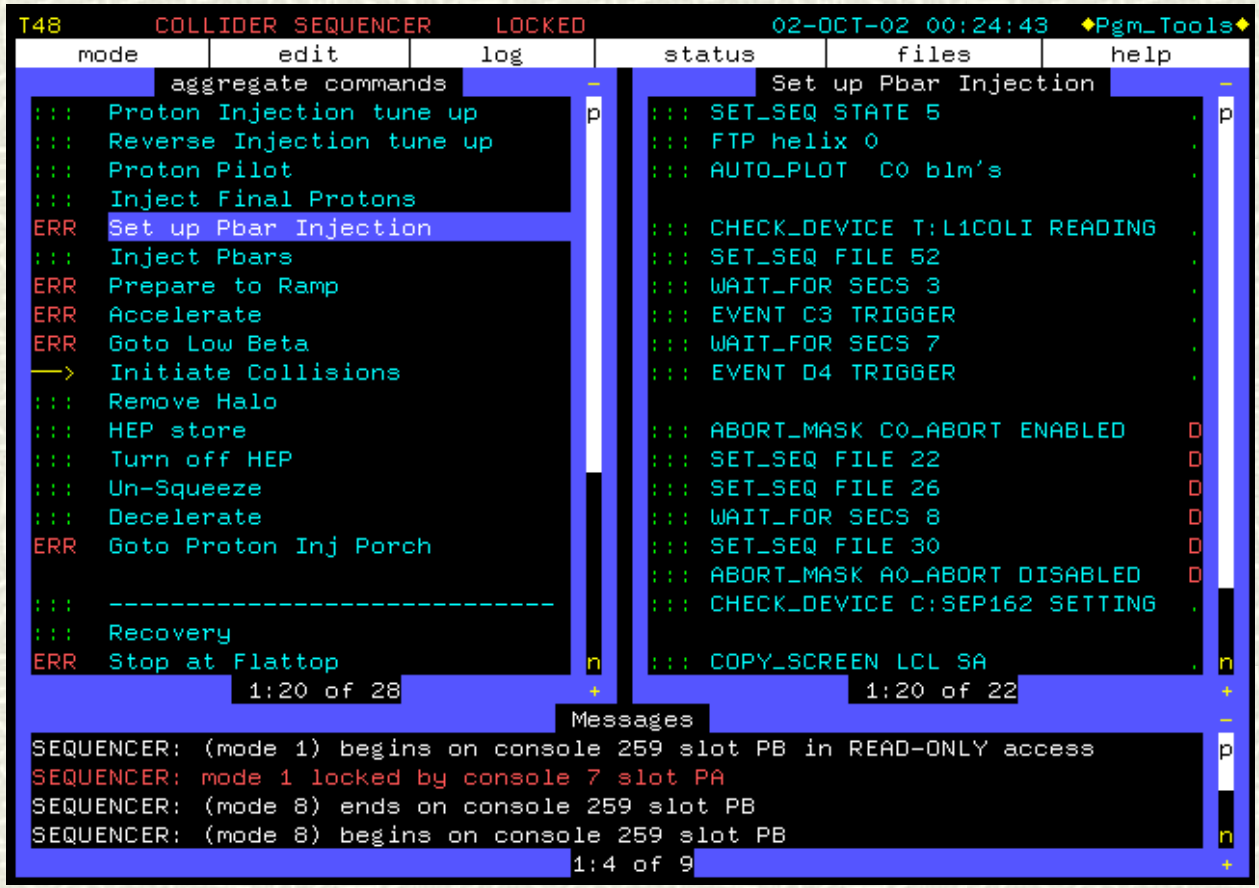
Tevatron Sequencer

Tune Up

Injection

Ramping

Squeeze and Initiate Collisions



Reset Tevatron Fields sit at injection lattice

- Store is terminated
- Un-squeeze , *Low beta supplies are ramped to injection lattice*
- Tevatron bus current is ramped to 150 GeV injection level.
- Operators perform a "dry squeeze"
  - Ramp to flattop
  - Ramp low beta to collision lattice and sit for 15 min

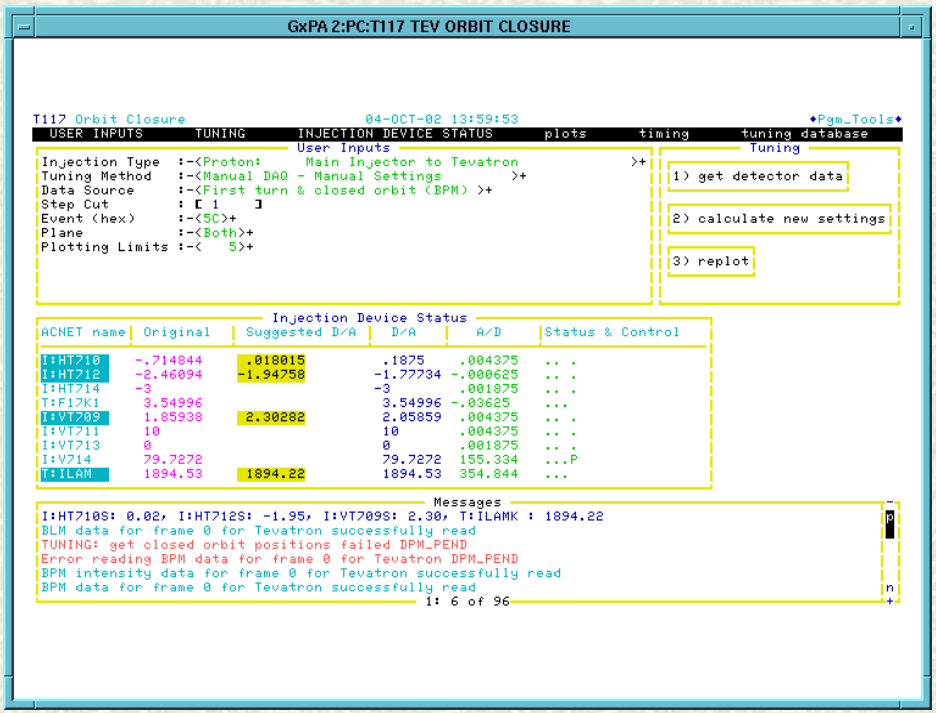
➢Un-squeeze and ramp down to 150 GeV injection lattice

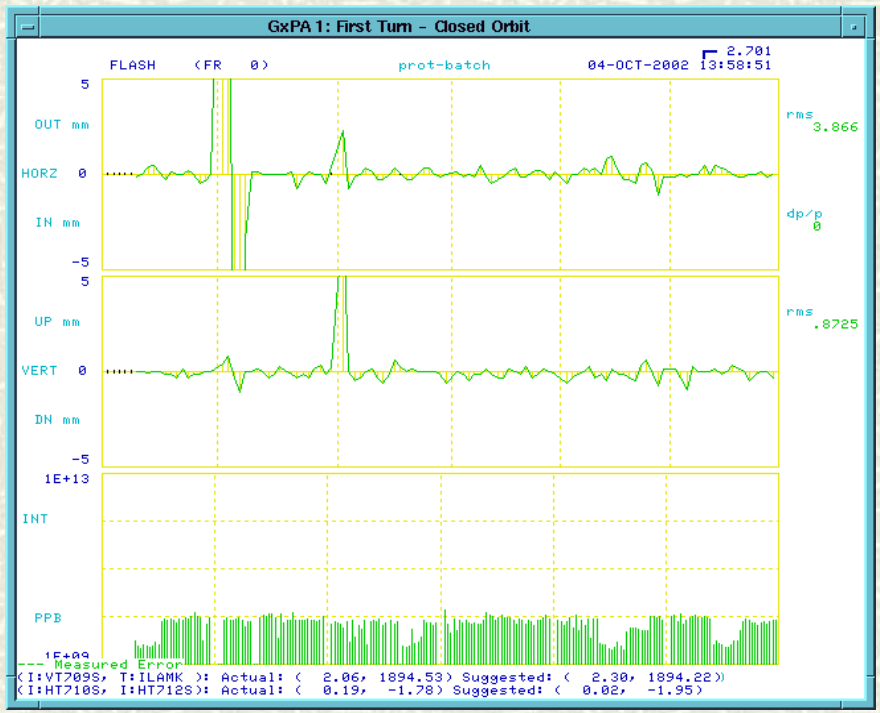
  ✓Tune and coupling drift auto compensation

  ✓Sextupole (b2) due to persistent currents compensation

✓Now ready for forward injection tune up

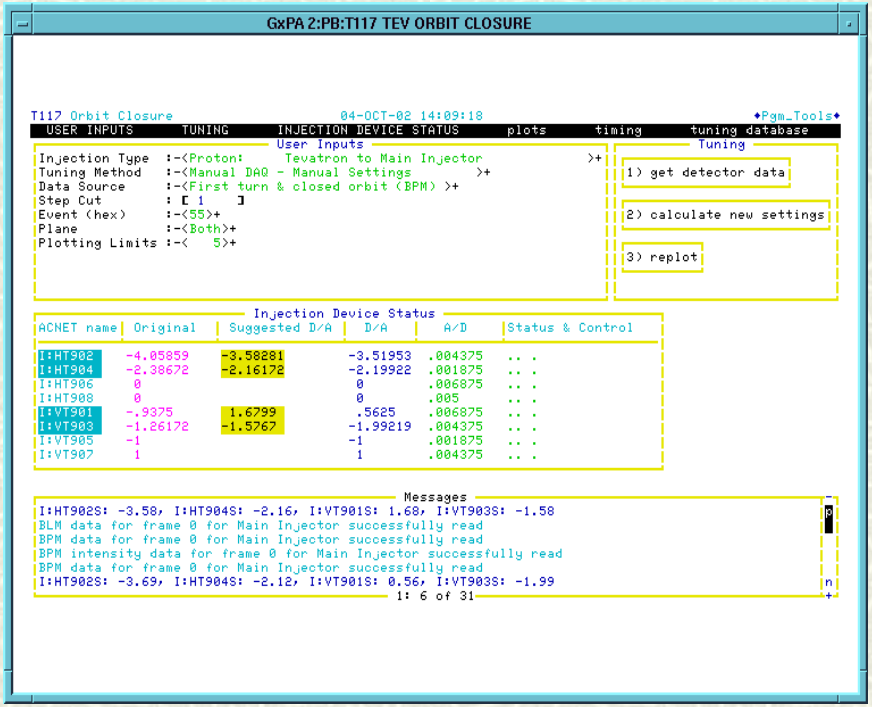
Tevatron Forward Proton Closure





Tevatron Reverse Proton Closure

Adjust the proton trajectory from the Tevatron through the A1 beamline back into the MI
Adjust closure back into the MI by matching the first turn orbit (flash) with the MI closed orbit.



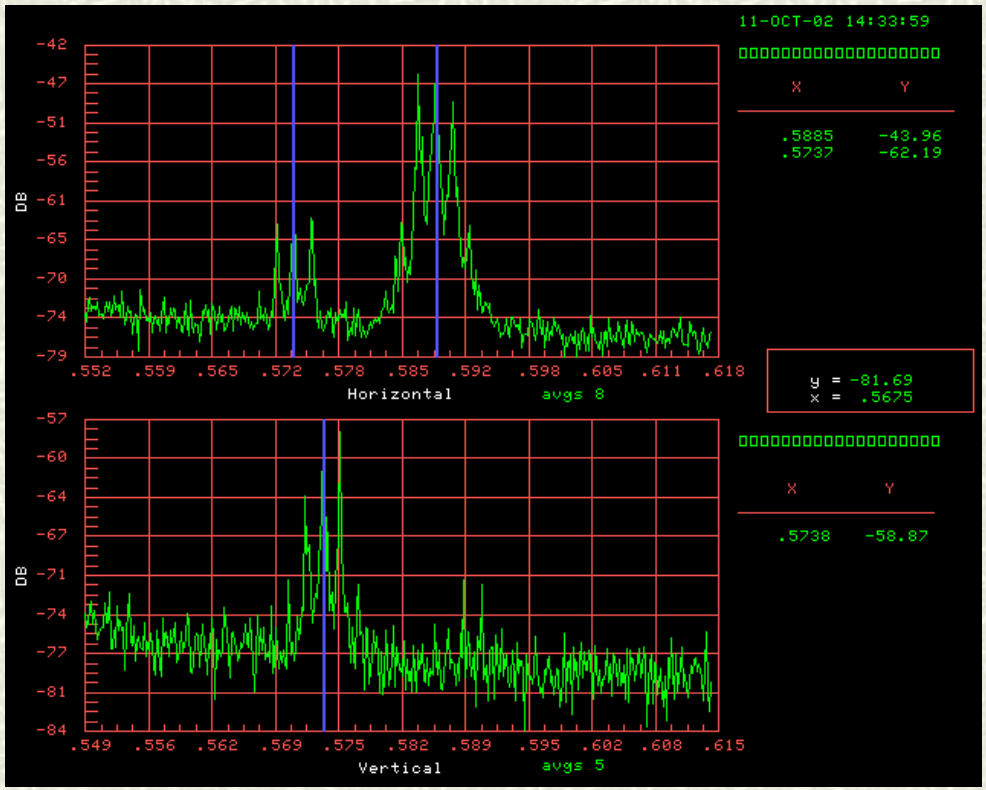
Program to read orbits and calculate/send corrections

MI difference orbit between first turn and closed orbit

Proton Pilot

Adjustment of proton tunes, chromaticity, and coupling on central orbit,

Setting nominal tunes on the central orbit
$Q_h = .583$ and $Q_v = .574$



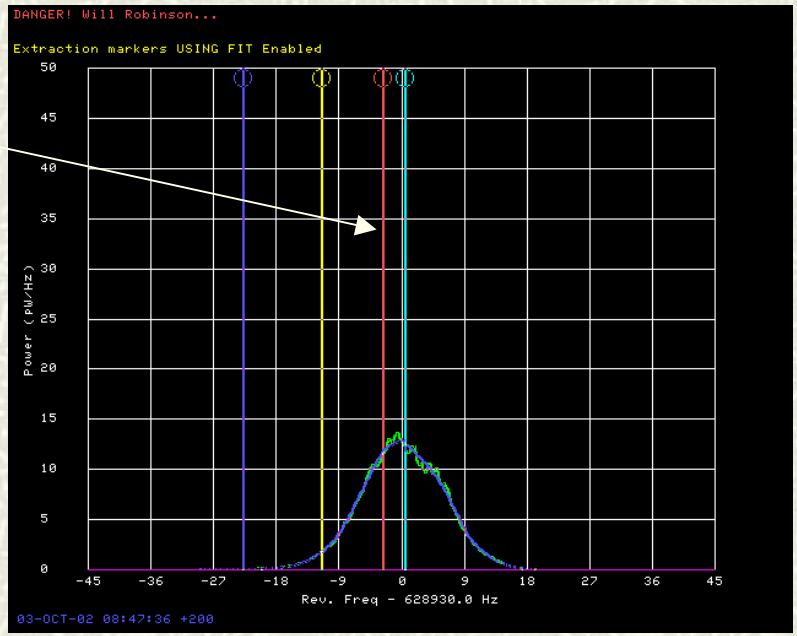
Once final protons are loaded, Tevatron is prepared for pbar injection

Unstacking Pbars from the Accumulator

>Once final protons are loaded, Tevatron is prepared for pbar injection

- The Tevatron Mode state variable is set to "ready for pbars"
- The Tevatron transfer state variable, *Next bunch*, is set for each transfer.
- Using the Pbar sequencer the operator requests a the number of pabrs to un-stack
- The proper RF curves are calculate and downloaded

Markers indicating the part of the core to be un-stacked defined by the amount of beam being requested.



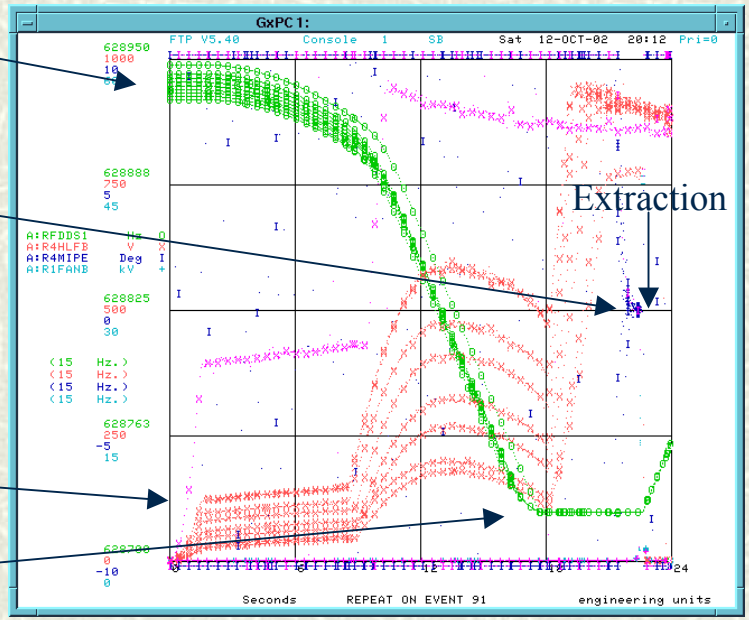
Unstacking Pbars from the Accumulator, con't

Capture freq.

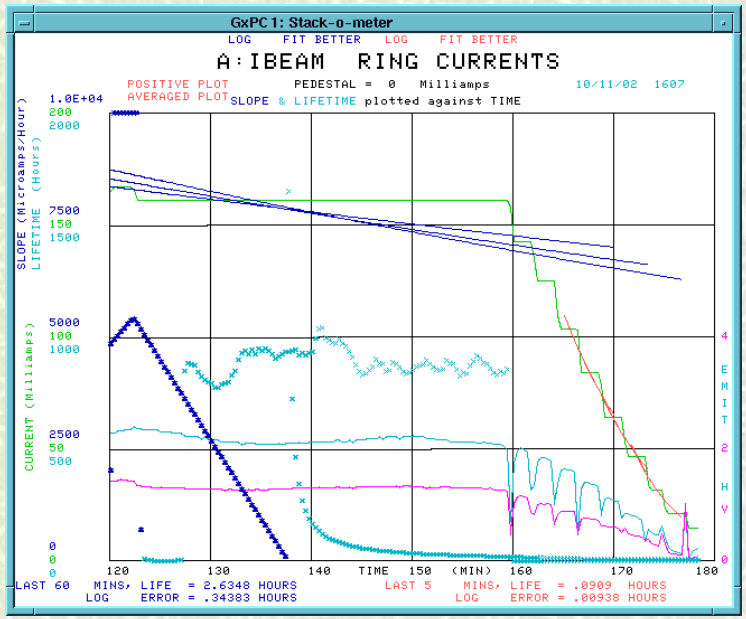
Phase locking to MI

Capture voltage

Extraction orbit freq

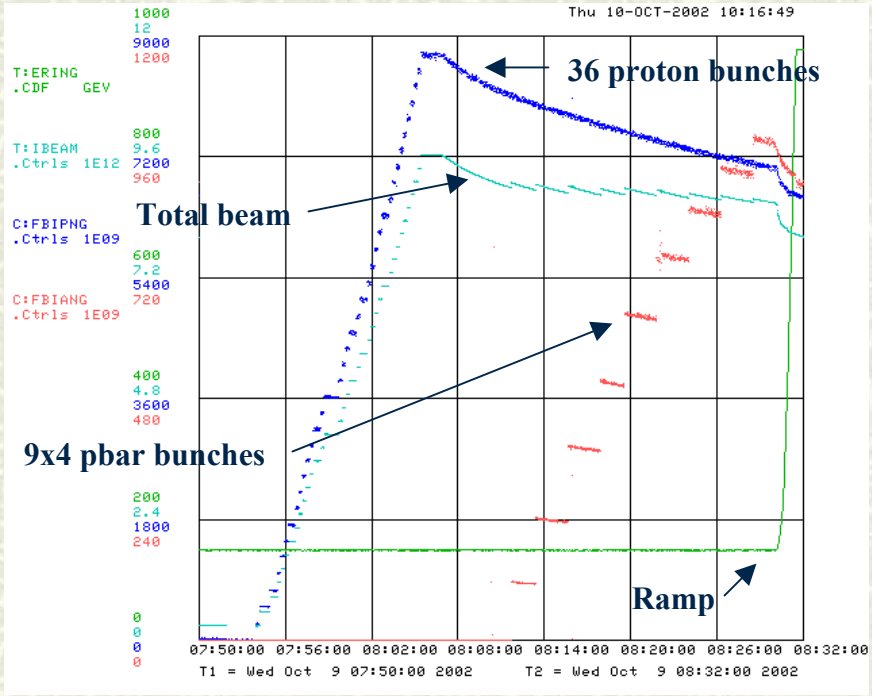


Monitoring Un-stacking ARF4 frequency and cavity voltage

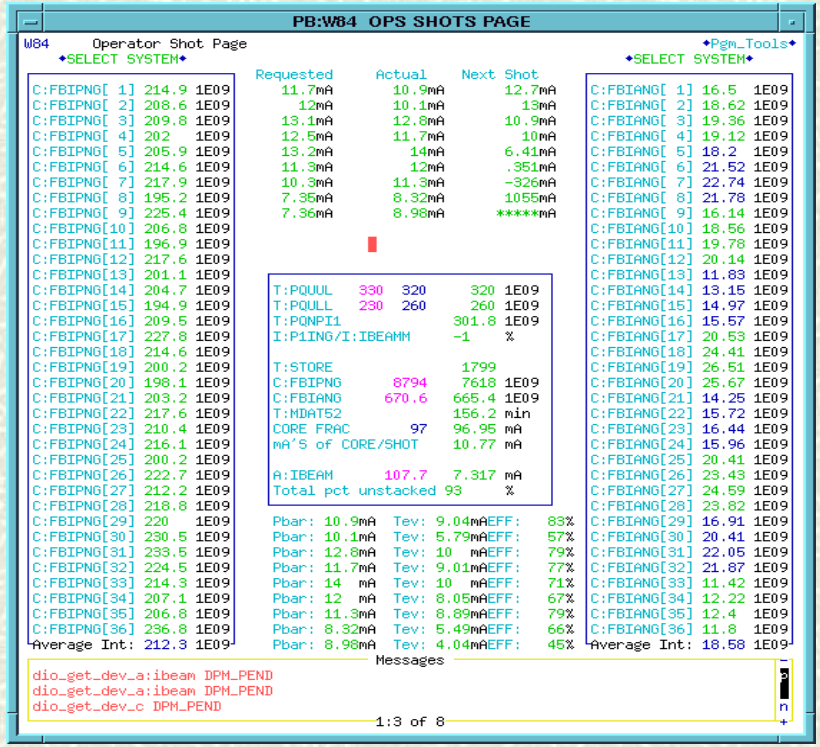


Monitoring the transverse emittance and Accumulator ring beam current

Tevatron Injection Protons/Pbars



Plot showing proton and pbar bunch intensity and total beam intensity



Program used to monitor (and set qualifier) Proton Intensity and monitor pbar injection process

Ramp ‘n Squeeze > Initiate Collisions

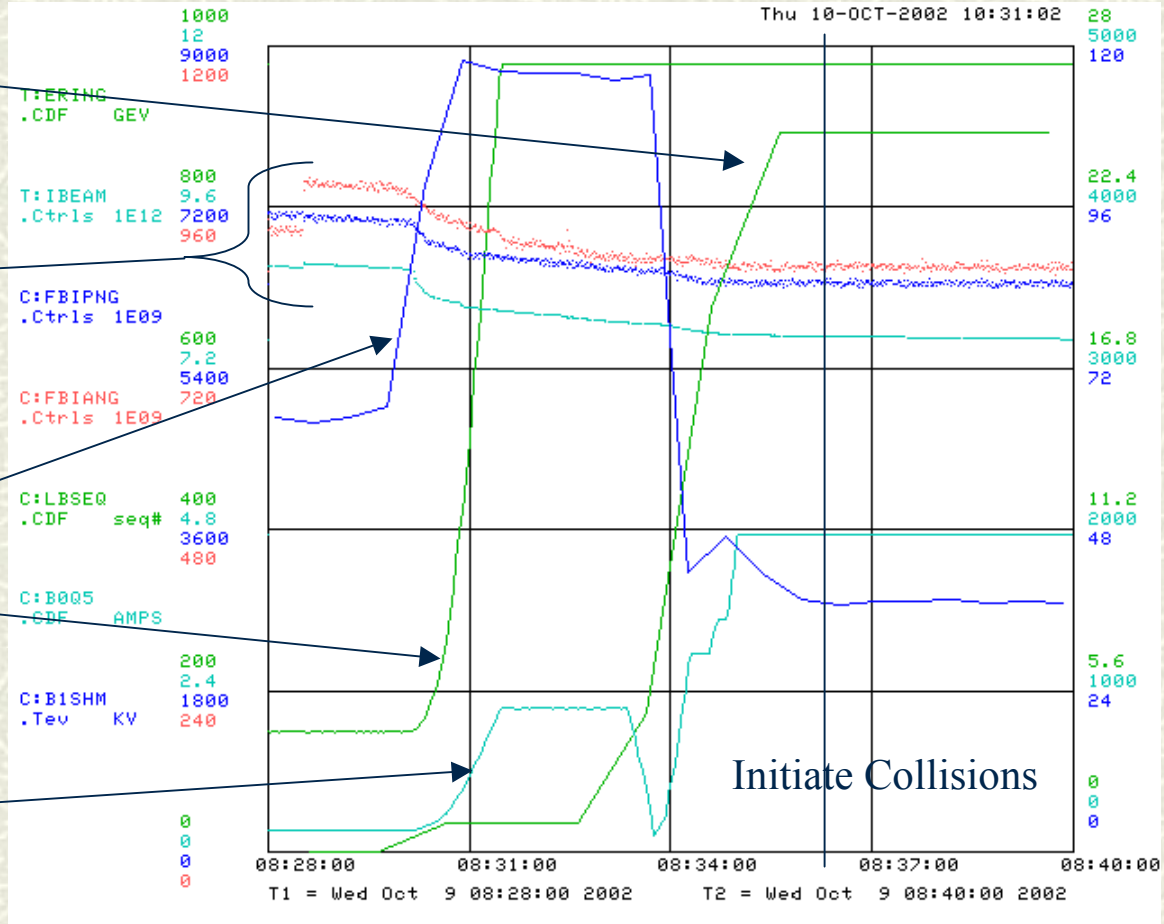
Low beta squeeze
Sequence number

Pbar, proton bunch
Total beam intensity

Separator Voltage

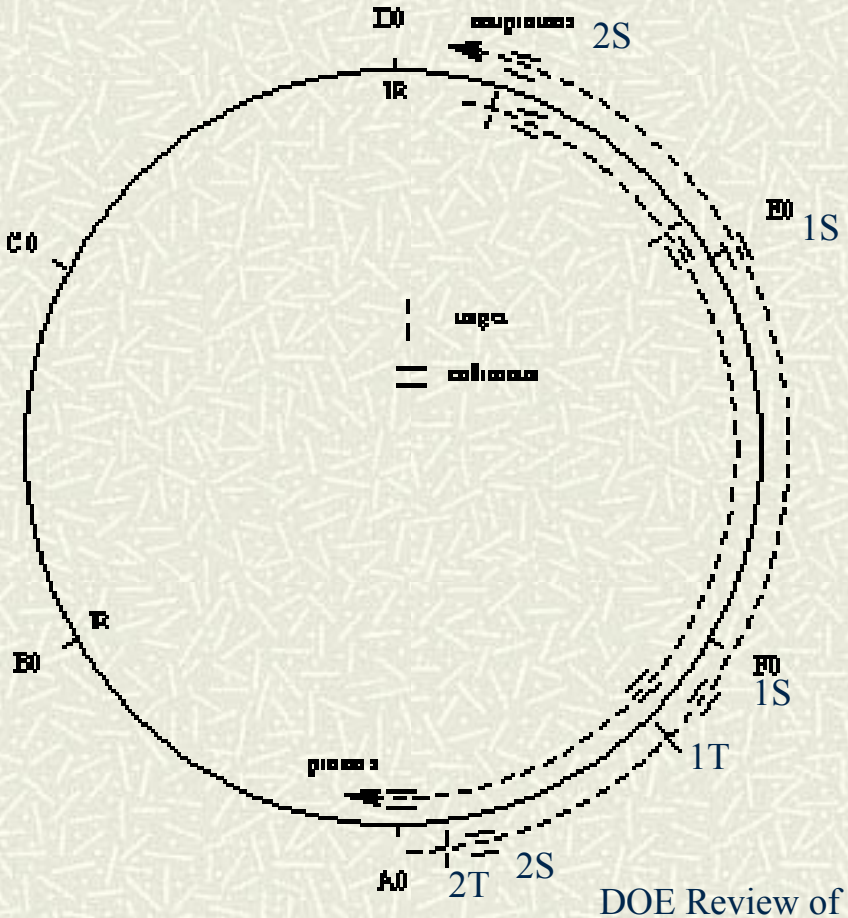
Tevatron Energy

Low Beta Quad 5

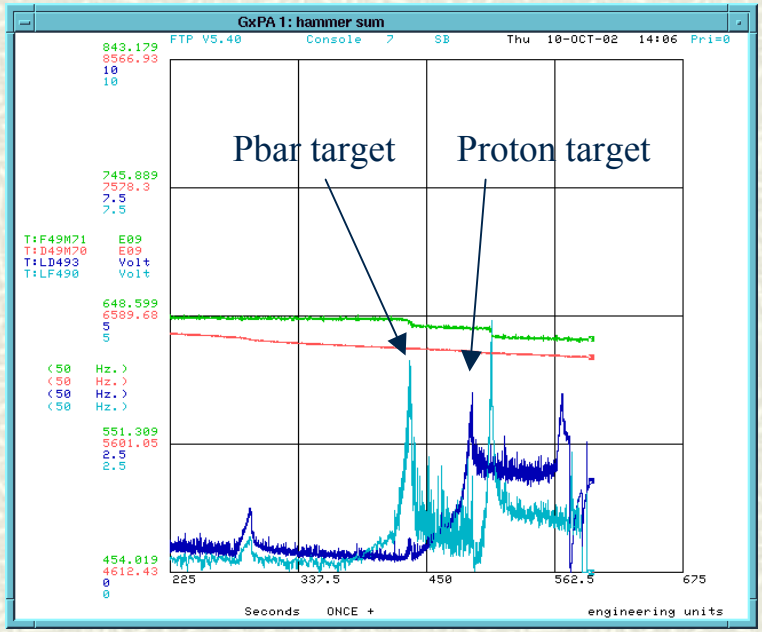


Remove Halo

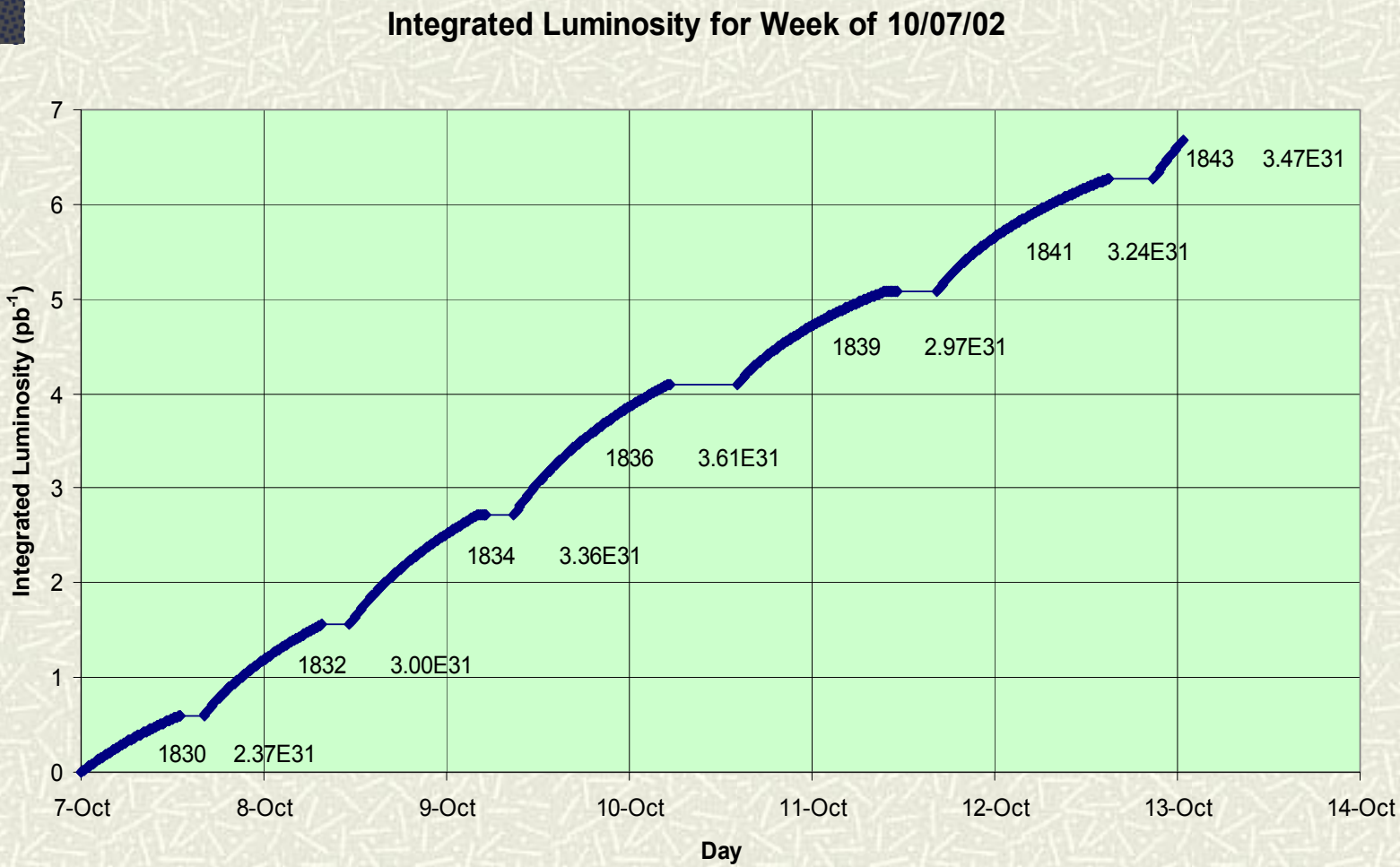
> Last step before HEP



- One set of proton and pbar collimators.
- Each set contains a single target and two secondary collimators.
- Two stage Halo removal
- Automated with beam loss feedback



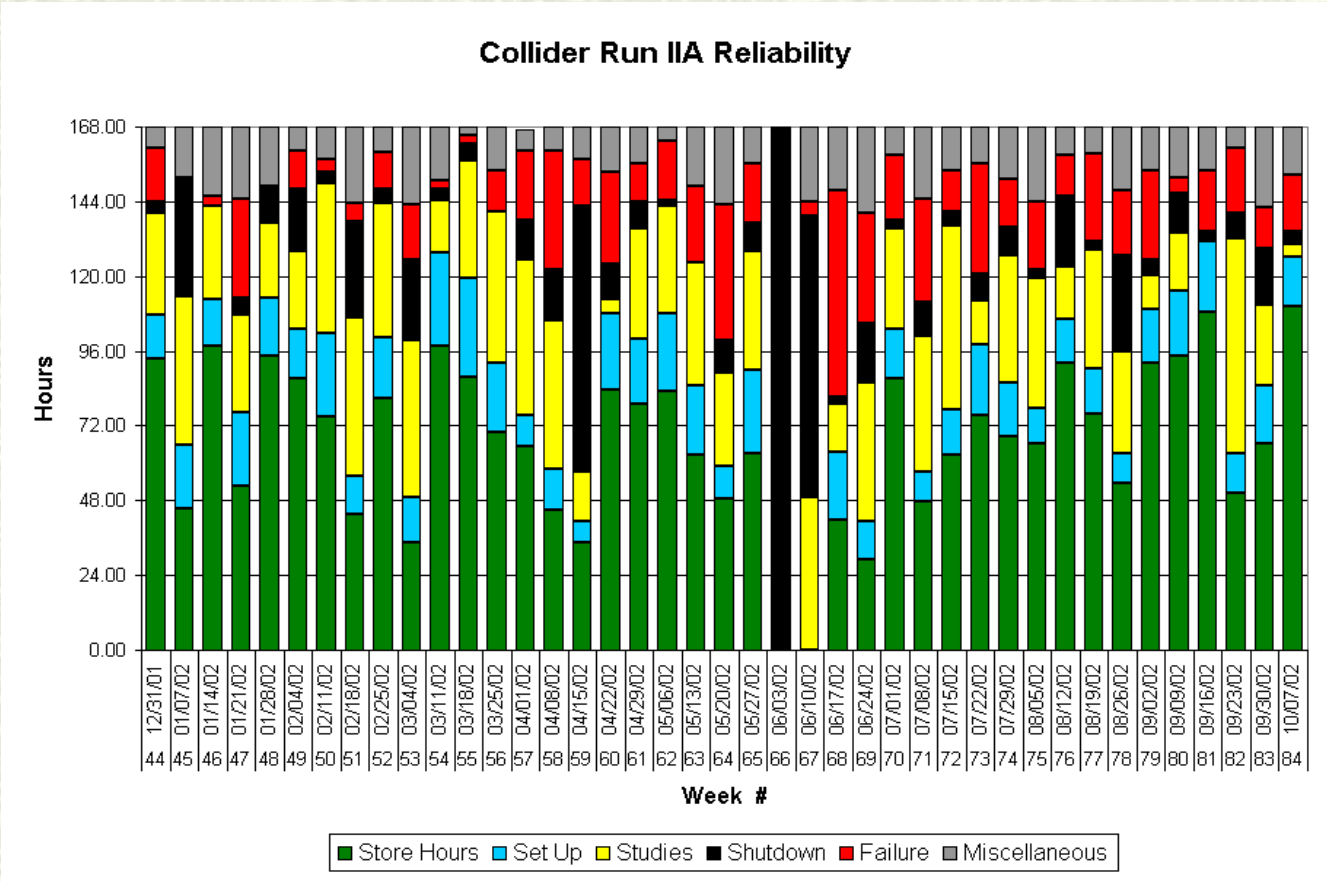
Luminosity, etc…



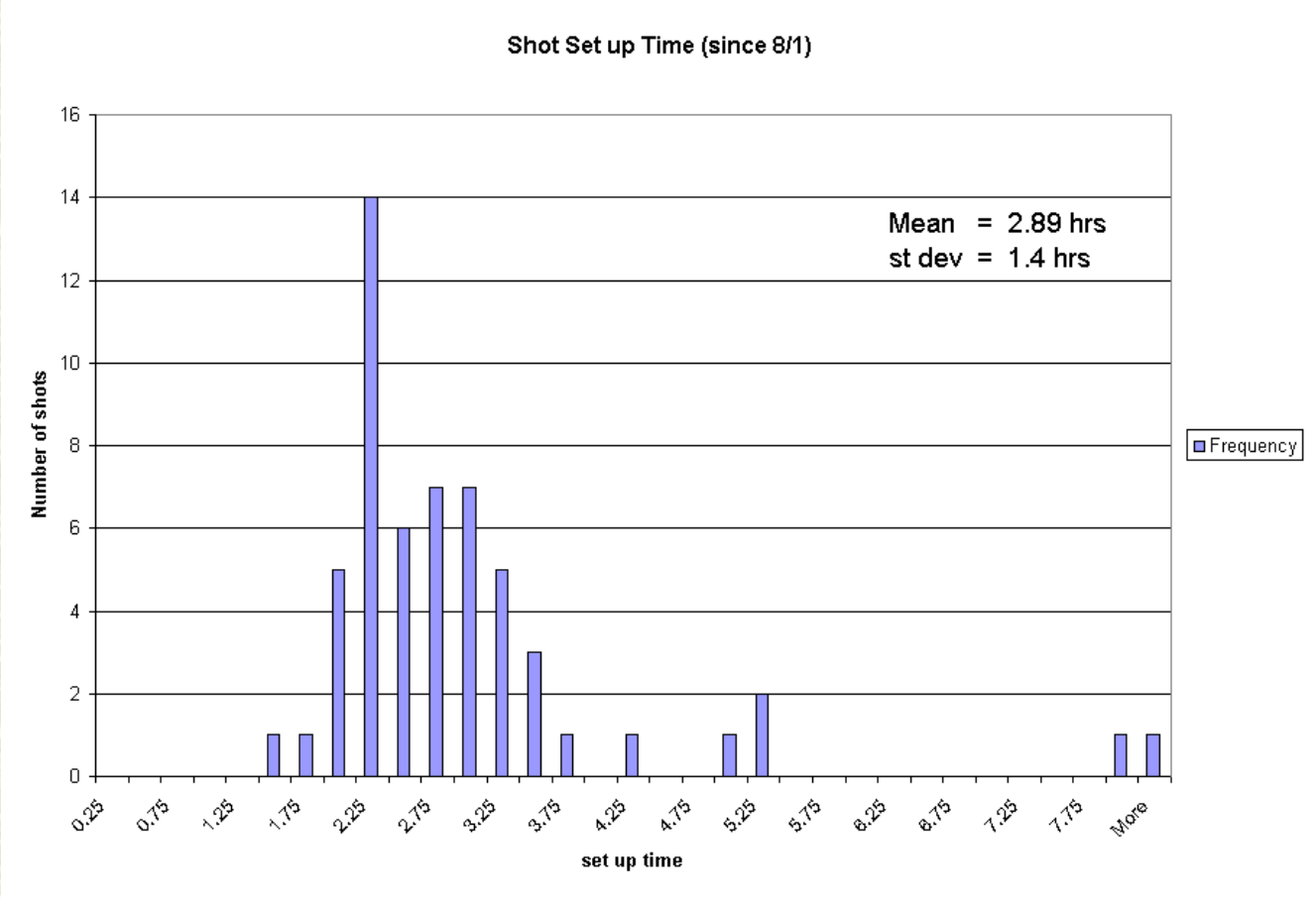
Stores, Studies, Set-up, etc…

Since August 5th

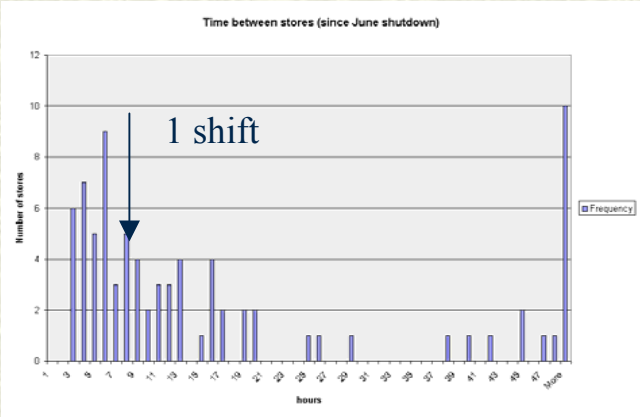
Store Hours	48%
Set up	10%
Studies	15%
Shutdown	7%
Failures	11%
Misc	9%



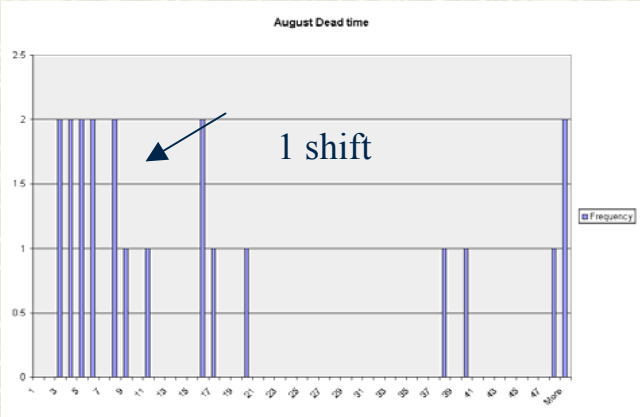
Shot Set-up time



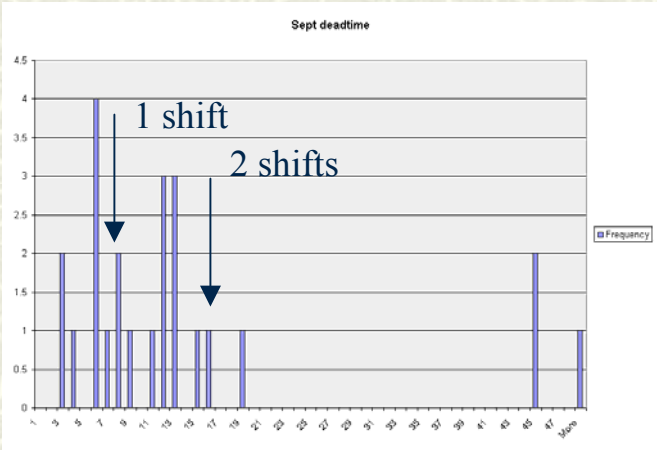
Time Between Stores



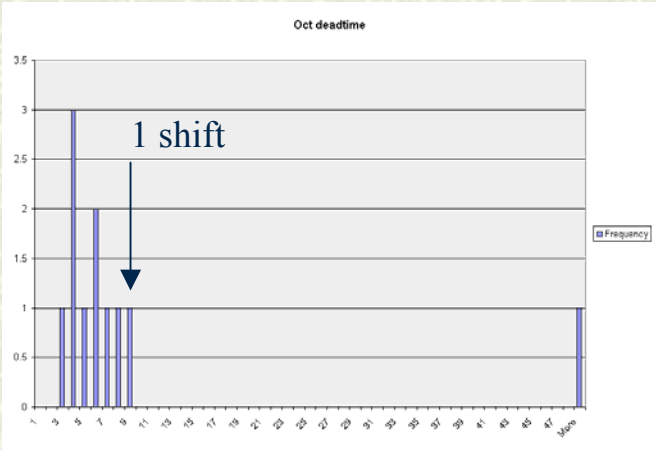
Since June Shutdown



August



September



October